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## (54) DIRECTION FINDER

(71) We, LICENTIA PATENT-VERWALTUNGS-G.M.B.H., of 1 Theodor-Stern-Kai, 6 Frankfurt 70, Federal Republic of Germany, a German Body Corporate, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to an arrangement for the automatic direction finding of N waves present in a frequency channel.

For the direction finding of N waves, it is known to set up 2N antennae and to evaluate the antennae voltages in an analog computer with the help of phase shifters and summing elements according to a predetermined programme (British Patent Specification No. 902,473).

It has also already been proposed to form, from the voltages of the 2N antennae, amplitude relationships and phase differences, to digitize these relationships or differences and to feed them to a digital computer, in which the incident directions of the N waves are determined according to a certain programme (British Patent Specification No. 1,144,206).

Furthermore it is known in direction finding technique to increase the number of antennae because redundant information reduces statistical influences (British Patent Specification No. 1,383,976).

In this case a considerable number of antennae can result which entails a like number of receivers and other devices (German Offenlegungsschrift No. 2,007,049).

Thus the expense can be considerable. A way to reduce this expense is known from German Offenlegungsschrift No. 1,516,876. In this case it is a question of a direction finder which contains a plurality of antennae after which are connected receivers as well as devices in which the antennae signals are scanned and digitized with a frequency which is at least twice as high as the receiving frequency. The direction finder further contains in addition to a digital computer, in which optionally switchable programmes are provided, switch means which on changeover of the programme cause only the digital values of those antennae to go into the computing operation which have the most favourable spatial installation in the case of the selected computing programme.

The invention seeks to enable a reduction of the expense necessary in accordance with the prior art.

According to the invention there is provided an arrangement for automatically finding the directions of incidence of a plurality of waves having respective different carrier frequencies within a predetermined frequency band, said arrangement comprising an antennae system providing directionally dependent output voltages, a sampling device for providing the instantaneous values of said output voltages at predetermined successive intervals, and a computer arranged to receive the instantaneous values of said output voltages at said intervals and programmed to determine therefrom the directions of incidence of said waves. Preferably, the output voltages are phase and amplitude dependent on the wave directions.

In the case of the invention the fact is used that interference fields are not stationary. Sequential instantaneous pick-ups of these fields supply new information, if the time intervals between the pick-ups are matched to the variation speed of the fields. In accordance with the invention therefore from the normally required number of antennae to resolve N waves and thus also in all following direction finding equipment, a cost saving is effected with respect to one part and the information loss caused by the saving is again equalized by the above-described sampling of the antennae signals.

The entire amount of information can then be subjected to similar algorithms for the resolution of the direction finding task, as are already known for the normal multi-wave direction finding techniques.

In the case of the invention it is often advantageous with regard to technology and computing technique, if between the antennae system and the sampling device there is connected an analog preprocessing unit which acts

as information transformer or information filter.

The invention may further permit multi-wave direction finding systems designed for N waves to be expanded to a greater number of waves in a simple manner.

To this end the device in accordance with the invention must be provided which permits, by sampling the antenna signals at time intervals which are matched to the variation rate of the interference fields, the amount of information over the fields to be increased.

The invention will now be further described, by way of example, with reference to the drawing, the single figure of which shows diagrammatically one embodiment of the invention.

A case with two incident waves (two wave case) can serve as an exemplary embodiment. As shown in the drawing, the non-directionally dependent voltage 2 as well as the $x$ and $y$-direction finding components 3, 4 of an Adcock 1 — which comprises a number of individual antenna arranged on a ring circuit or circle — are fed to a Watson-Watt 3-channel amplifier 5. Preferably, the Watson-Watt direction finding device is connected to a conventional visual apparatus. The direction finding arrangement can be used at the same time both for the original direction finding function and for multi-wave direction finding.

As is well known, for a two wave case the following applies:

Voltage in the non-directional channel

$$z = A_1 e^{i(\omega_1 t+\varphi_1)} + A_2 e^{i(\omega_2 t+\varphi_2)}$$

Voltage in the first direction finding channel

$$y = A_1 \sin\alpha_1 e^{i(\omega_1 t+\varphi_1)} + A_2 \sin\alpha_2 e^{i(\omega_2 t+\varphi_2)}$$

Voltage in the second direction finding channel

$$x = A_1 \cos\alpha_1 e^{i(\omega_1 t+\varphi_1)} + A_2 \cos\alpha_2 e^{i(\omega_2 t+\varphi_2)}$$

$A_1$, $A_2$ are the amplitude of the two waves, $\alpha_1$, $\alpha_2$ the azimuths,

$\omega_1$ and $\omega_2$ the circuit frequencies and $\varphi_1$, $\varphi_2$ the phases.

In a scanner 6 the amplified antenna signals are sampled or scanned at the time $t=0$ for the first time and at the time $t=t_0$ for the second time.

The scanning is controlled by a digital computer 8 as is indicated in the Figure by a feed line 9. From the scanning is obtained a sequence of pulses which are digitized in an analog digital converter 7. The digital values are fed to the digital computer 8 which computes from them, by means of predetermined programmes the desired incident angle $\alpha_1$ and $\alpha_2$.

In the following, the computations upon which the programmes used in the digital computer 8 are based are gone into in somewhat greater detail.

With the abbreviations

$$\delta_1 = e^{i\varphi_1}; \quad \delta_2 = e^{i\varphi_2}; \quad \gamma_1 = e^{i\omega_1 t_0}; \quad \gamma_2 = e^{i\omega_2 t_0}$$

At time $t=0$

$$\begin{cases} z_1 = A_1\delta_1 + A_2\delta_2 \\ y_1 = A_1\sin\alpha_1\delta_1 + A_2\sin\alpha_2\delta_2 \\ x_1 = A_1\cos\alpha_1\delta_1 + A_2\cos\alpha_2\delta_2 \end{cases}$$

and at time $t=t_0$

$$\begin{cases} z_2 = A_1\delta_1\gamma_1 + A_2\delta_2\gamma_2 \\ y_2 = A_1\sin\alpha_1\delta_1\gamma_1 + A_2\sin\alpha_2\delta_2\gamma_2 \\ x_2 = A_1\cos\alpha_1\delta_1\gamma_1 + A_2\cos\alpha_2\delta_2\gamma_2 \end{cases}$$

In this case $z_1$, $z_2$, $y_1$, $y_2$, $x_1$, $x_2$ are measured voltage values. If the present equations are resolved in the computer 8 there results for the still unknown values:

$$A_1\cos\alpha_1\delta_1 = \frac{\begin{vmatrix} x_1 & 1 \\ x_2 & \gamma_2 \end{vmatrix}}{\begin{vmatrix} 1 & 1 \\ \gamma_1 & \gamma_2 \end{vmatrix}} \qquad (1)$$

$$A_1\sin\alpha_1\delta_1 = \frac{\begin{vmatrix} y_1 & 1 \\ y_2 & \gamma_2 \end{vmatrix}}{\begin{vmatrix} 1 & 1 \\ \gamma_1 & \gamma_2 \end{vmatrix}} \qquad (2)$$

$$A_2\cos\alpha_2\delta_2 = \frac{\begin{vmatrix} 1 & x_1 \\ \gamma_1 & x_2 \end{vmatrix}}{\begin{vmatrix} 1 & 1 \\ \gamma_1 & \gamma_2 \end{vmatrix}} \qquad (3)$$

$$A_2\sin\alpha_2\delta_2 = \frac{\begin{vmatrix} 1 & y_1 \\ \gamma_1 & y_2 \end{vmatrix}}{\begin{vmatrix} 1 & 1 \\ \gamma_1 & \gamma_2 \end{vmatrix}} \qquad (4)$$

$$A_1\delta_1 = \frac{\begin{vmatrix} z_1 & 1 \\ z_2 & \gamma_2 \end{vmatrix}}{\begin{vmatrix} 1 & 1 \\ \gamma_1 & \gamma_2 \end{vmatrix}} \qquad (5)$$

$$A_2\delta_2 = \frac{\begin{vmatrix} 1 & z_1 \\ \gamma_1 & z_2 \end{vmatrix}}{\begin{vmatrix} 1 & 1 \\ \gamma_1 & \gamma_2 \end{vmatrix}} \qquad (6)$$

Firstly in addition the $\gamma_1$, $\gamma_2$ are to be determined in an intermediate process. If one uses for this $B_1=A_1 \cos \alpha_1 \delta_1$ and $B_2=A_1 \sin \alpha_1 \delta_1$ and determines therefrom

$$B=\frac{B_2}{B_1},$$

that is to say a real number, then for this applies as is well known (* means conjugated complex)

$$B=B^*$$

or

$$\frac{B_2}{B_1}=\frac{B_2^*}{B_1^*}$$

This gives in detail the relationship

$$B_1B_2^*-B_2B_1^*=0.$$

The expressions (1) and (2) are inserted in this equation. There then results for $\gamma_2$ the quadratic equation

$$a\gamma_2^2+ib\gamma_2-a^*=0$$

with the two solutions

$$\gamma_2=\frac{-ib\pm\sqrt{4aa^*-b^2}}{2a}$$

and

$$a=y_1x_2^*-y_2^*x_1 \quad ib=x_1y_1^*-x_1^*y_1+x_2y_2^*-x_2^*y_2$$

Similarly, the solution for $\gamma_1$ is

$$\frac{-ib\pm\sqrt{4aa^*-b^2}}{2a}$$

Then one goes into the expressions (1) to (6) with $\gamma_1$ and $\gamma_2$.

Now from these can be computed without effort the direction finding values $\alpha_1$, $\alpha_2$. With this the direction finding task for the two wave case is solved. An appropriate number of samples is required for more than two waves.

WHAT WE CLAIM IS:—

1. An arrangement for automatically finding the directions of incidence of a plurality of waves having respective different carrier frequencies within a predetermined frequency band, said arrangement comprising an antennae system providing directionally dependent output voltages, a sampling device for providing the instantaneous values of said output voltages at predetermined successive intervals, and a computer arranged to receive the instantaneous values of said output voltages at said intervals and programmed to determine therefrom the directions of incidence of said waves.

2. An arrangement according to claim 1, wherein the output voltages are phase and amplitude dependent on the wave directions.

3. An arrangement according to claim 1 or claim 2, wherein a device for analog preprocessing is located between the antennae system and the sampling device.

4. An arrangement according to claim 3, wherein the antennae system and the device for analog preprocessing are constructed as a conventional direction finding system.

5. An arrangement according to claim 3 or claim 4, wherein the device for analog preprocessing is constructed as a Watson-Watt direction finding device.

6. An arrangement according to claim 5, wherein the Watson-Watt direction finding device is connected to a conventional visual apparatus.

7. An arrangement according to any one of claims 4 to 6, wherein the direction finding system is constructed and can be used at the same time both for the original direction finding function and for multi-wave direction finding.

8. An arrangement according to any preceding claim, wherein the antennae system comprises an Adcock system.

9. An arrangement for automatically finding the directions of incidence of a plurality of waves substantially as described herein with reference to the drawing.

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1475414 COMPLETE SPECIFICATION

1 SHEET This drawing is a reproduction of the Original on a reduced scale